

# Active Control of Combustor Instability Shown to Help Lower Emissions

In a quest to reduce the environmental impact of aerospace propulsion systems, extensive research is being done in the development of lean-burning (low fuel-to-air ratio) combustors that can reduce emissions throughout the mission cycle. However, these lean-burning combustors have an increased susceptibility to thermoacoustic instabilities, or high-pressure oscillations much like sound waves, that can cause severe high-frequency vibrations in the combustor. These pressure waves can fatigue the combustor components and even the downstream turbine blades. This can significantly decrease the safe operating life of the combustor and turbine. Thus, suppression of the thermoacoustic combustor instabilities is an enabling technology for lean, low-emissions combustors. Under the Aerospace Propulsion and Power Base Research and Technology Program, the NASA Glenn Research Center, in partnership with Pratt & Whitney and United Technologies Research Center, is developing technologies for the active control of combustion instabilities.

With active combustion control, the fuel is pulsed to put pressure oscillations into the system. This cancels out the pressure oscillations being produced by the instabilities. Thus, the engine can have lower pollutant emissions *and* long life.

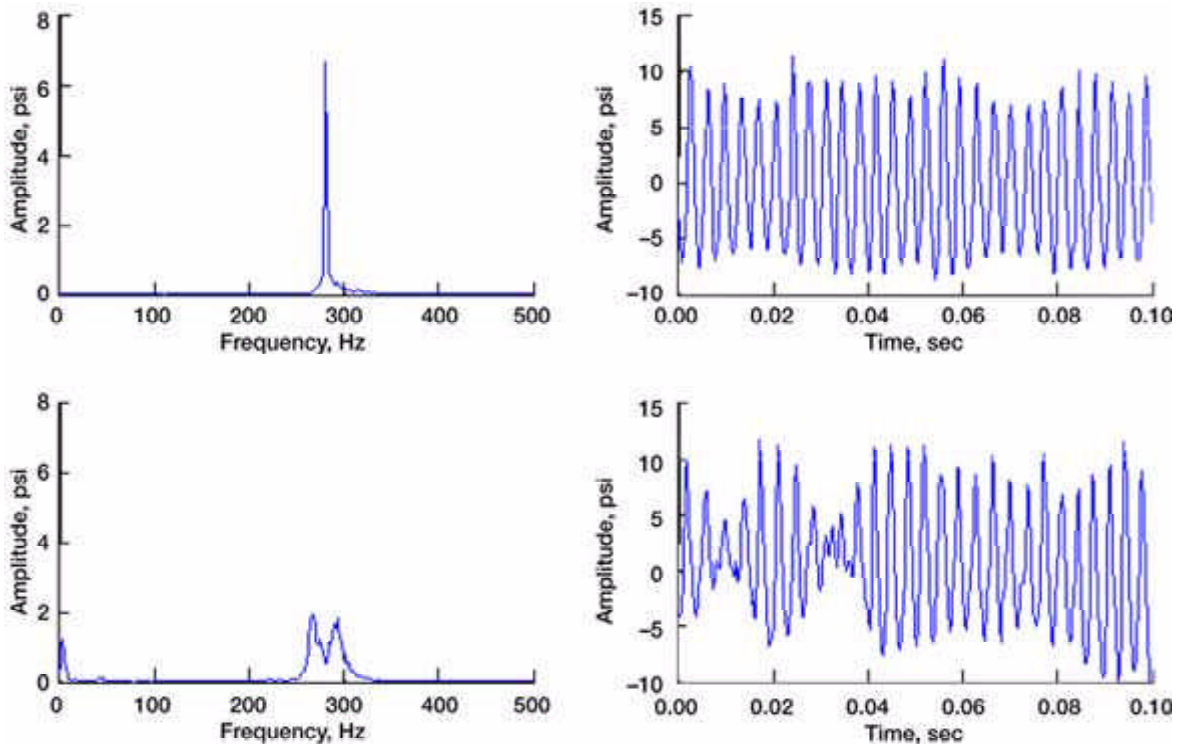


*Pulsating fuel modulations are used to suppress combustion instability.*

Long description: Fuel stream proceeding from a fuel injector nozzle. Imposed on the fuel stream are fuel pulsations caused by the fuel delivery system. These pulsating fuel modulations are used to suppress combustion instability.

The use of active combustion instability control to reduce thermo-acoustic-driven combustor pressure oscillations was demonstrated on a single-nozzle combustor rig at United Technologies. This rig has many of the complexities of a real engine combustor (i.e., an actual fuel nozzle and swirler, dilution cooling, etc.). Control was demonstrated through modeling, developing, and testing a fuel-delivery system able to pulse the fuel at

the 280-Hz instability frequency. The preceding figure shows the capability of this system to provide high-frequency fuel modulations. Because of the high-shear contrarotating airflow in the fuel injector, there was some concern that the fuel pulses would be attenuated to the point where they would not be effective for control. Testing in the combustor rig showed that open-loop pulsing of the fuel was, in fact, able to effectively modulate the combustor pressure. To suppress the combustor pressure oscillations due to thermoacoustic instabilities, it is desirable to time the injection of the fuel so that it interferes with the instability. A closed-loop control scheme was developed that uses combustion pressure feedback and a phase-shifting controller to time the fuel-injection pulses. Some suppression of the pressure oscillations at the 280-Hz instability frequency was demonstrated (see the next figure). However, the overall peak-to-peak pressure oscillations in the combustor were only mildly reduced. Improvements to control hardware and control methods are being continued to gain improved closed-loop reduction of the pressure oscillations.



*Power spectra and time history of the combustor pressure oscillations without and with instability control. Top: Without instability control; rms pressure amplitude, 5.35 psi.*

*Bottom: With instability control; rms pressure amplitude, 5.01 psi.*

Long description: Top: Power spectra and time history for the combustor pressure with the uncontrolled combustion instability. The combustion instability shows as a clear peak in the spectra at 280 Hz. The time history shows pressure oscillations of about  $\pm 10$  psi, with an rms value of 5.35 psi. Bottom: Same power spectra and time history, but with the instability control active. The spectra now shows that the peak at 280 Hz is no longer present, but peaks adjacent to 280 Hz have appeared. The time history shows that the pressure oscillations have been reduced part of the time, with a corresponding decrease in the rms value to 5.01 psi

**Find out more about this research:**

Active Combustion Control project

Glenn's Combustion Branch <http://www.grc.nasa.gov/WWW/combustion/>

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